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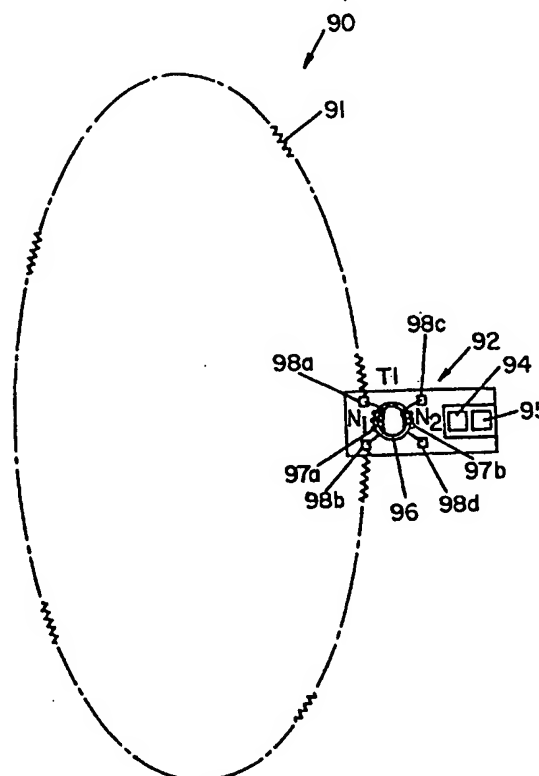
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B60C 23/04	A1	(11) International Publication Number: WO 99/29522
		(43) International Publication Date: 17 June 1999 (17.06.99)
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(54) Title: **PNEUMATIC TYRE WITH AN ANTENNA FOR RADIO TRANSPONDER**

(57) Abstract

An annular apparatus is embedded in a substantially non-conductive elastomeric material (22) located within the toroidal region of a pneumatic tire (10). The apparatus is coaxially positioned with respect to the tire or wheel and preferably is embedded in the tire at its equatorial plane (EP), and includes a radio-frequency transponder system (30), including an integrated circuit chip (28), and optional sensors in the chip or associated with the chip. The integrated circuit chip (28) of the transponder system (30) has at least the capacity to transmit data relating to tire or wheel identification. The antenna (26) comprises a springy steel wire or filament. Electrical leads (32) of the chips (28) are electrically associated with each end of the antenna (26).



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PNEUMATIC TYRE WITH AN ANTENNA FOR RADIO TRANSPONDER

Technical Field

5 This invention relates to an apparatus, and an antenna for electronically transmitting tire or wheel identification or other data at radio frequency. The apparatus includes a radio-frequency transponder comprising an integrated circuit chip having data capacity at least sufficient to retain identification information for the tire or wheel. Other data, such as the inflation pressure of the tire or the temperature of the tire or wheel at the transponder location, can be transmitted by the
10 transponder along with the identification data.

 As illustrated by the references described below, it is known in the art to employ an annular antenna to transmit, at radio frequencies, data from a transponder contained within the structure of a tire or tire and wheel assembly. In practice, however, it is very difficult to do this with an antenna incorporated into the tire during the course of its manufacture. Both radial ply and bias
15 ply tires undergo a substantial diametric enlargement during the course of manufacture. Bias ply tires are expanded diametrically when inserted into a curing press, which typically has a bladder that forces the green tire into the toroidal shape of the mold enclosing it. Radial ply tires undergo diametric expansion during the tire building or shaping process and a further diametric expansion during the course of curing. Any electronic circuitry coupled to an annular antenna built into the
20 tire must be able to have its electrical connections survive this diametric enlargement of the tire during its manufacture. Furthermore, the annular antenna must be able to survive the repeated deformations occurring during tire use.

 It is desirable to interrogate or read the data contained within or transmitted by the transponder at any position around the 360° circumference of the pneumatic tire.

25 A desirable feature of a transponder apparatus in a tire is that it be able to transmit tire pressure data if a pressure sensor is used in conjunction therewith. Also, it is desirable that the transponder be able to transmit information related to the temperature of the tire at the transponder location.

Background Art

30 Tire safety indicator means have been provided in the prior art to indicate when the tread of a tire is worn to the point where the tread or the tire must be replaced. See for example De Cicco in U.S. Patent 3,770,040.

 As the art has advanced, systems for monitoring vehicle tire pressure and the like have been proposed wherein a transmitter and a receiver are mounted on a vehicle body, and
35 magnetically coupled inductor and enhancer circuits are carried on the vehicle wheel to provide monitoring of vehicle tire pressure, as described by Allen in U.S. Patent 4,588,978. Other devices

to monitor tire pressure have been proposed by Galasko et al., in U.S. Patent 4,578,992, who teach a coil mounted in a tire which forms, with a capacitor, a passive oscillatory circuit. The circuit is energized by pulses supplied via a coil positioned outside the tire and secured to the vehicle, and the frequency in the passive oscillatory circuit is varied with tire pressure due to changes caused to the capacitance value of the capacitor. The frequency in the circuit is sensed by a coil positioned outside the tire and secured to the vehicle.

Milheiser, in U.S. Patent 4,730,188, teaches the use of a passive integrated transponder which is attached to or imbedded in an item to be identified, and is excited by an inductive coupling from an interrogator.

Fiorletta, in U.S. Patent 5,289,160, teaches a wireless tire pressure monitoring system which warns a driver of low pressure in one or more tires. Fiorletta teaches that a pressure transducer, transmitter and antenna are integrally housed and mounted to the tire stem of a tire. When the pressure transducer senses a tire pressure below a pre-selected pressure, the transmitter broadcasts a radio frequency signal that, upon detection by a receiver mounted on the vehicle, warns the driver. In a preferred embodiment, the transmitter is a device that is periodically interrogated by an RF signal from a transmitter on the vehicle.

In PCT Applications WO90/12474 and 90/01754, it is taught that electronic transponders can be embedded within or on vehicle tires with wire loop antennas and electromagnetically actuated by signals from an interrogator coil. The application indicates that the transponder responds to actuation by producing a shifted frequency modulated with synchronization pulses and identifying digital information, and can also be used to include information on the condition and environment of the tire.

Hettich et al., in U.S. Patent 5,140,851, teach a circuit arrangement for monitoring air volume in vehicle tires which provides correction for the temperature of the tire. The patent states that the temperature and pressure measurement value of the tire is measured by a rotating sensor on the wheel, which is monitored, and the data fed to a correction circuit which also receives a plurality of correction parameters. A corrected value for the temperature or for the air pressure in the tire is transmitted at output of the correction circuit as a function of the correction parameters.

PCT Application WO92/20539 provides an abnormal tire condition warning system which comprises a housing, a band for mounting the housing on the tire rim, a sensor for monitoring the condition within the tire, circuitry operatively connected to the sensor for generating radio signals indicative of the tire condition, a impedance supply operatively connected to the circuitry, a

centrifugal switch and a receiver for receiving the radio signals.

Dunn et al., in U.S. Patent 4,911,217 describes a radio-frequency tire identification system having an integrated circuit chip transponder.

5 Pollack et al., in U.S. Patent 5,181,975, teach a tire having an integrated circuit transponder which comprises a coil antenna of small enclosed area, as compared to the area enclosed by the bead of the tire, which acts as a primary winding of a transformer. The coil is planar in shape, and when positioned between the innerliner and the carcass ply of the tire, may include a pressure sensor.

10 Brown et al., in U.S. Patent 5,218,861, teach a pneumatic tire having an integrated circuit transponder which has an antenna which is coupled by electric or magnetic fields to the bead of the tire.

Koch et al., in U. S. Patent 5,500,065 teaches locating a monitoring device radially inward of the inner liner in a pneumatic tire, somewhere in the crown portion of the tire.

Disclosure of the Invention

15 It is an object of the invention to provide an apparatus which can be built into a tire, is small enough that it does not have a noticeable affect on the operation of the tire, and is sturdy enough to withstand the millions of deformations that a tire undergoes during its use on a vehicle. Other objects of the invention will be apparent from the following description and claims.

Definitions

20 The following definitions are provided to facilitate the reading of the specification and the understanding of the invention.

"Heterodyne" refers to the additional sum and difference frequencies produced by mixing two sinusoidal alternating current sources.

"Transmitter" refers to a radio frequency emitter.

25 "Receiver" refers to a radio frequency receptor.

"Interrogator" refers to a transmitter-receiver decoder combination.

"Lines of flux" refers to magnetic intensity and the direction of the magnetic intensity vector.

30 "Transponder" refers to a receiver of RF energy capable of transmitting coded information to an interrogator (scanner).

"Equatorial plane (EP)" refers to the plane intersected at the tire centerline.

"Radially" refers to a radius line from a tire axis to a tire circumference, and lines parallel

thereto.

Brief Description of Drawings

Fig. 1 illustrates a cross section of a RMT (radial medium truck) tire having the apparatus of the invention embedded in the crown of the tire.

5 Fig. 2 illustrates a cutaway portion of Fig. 1 viewed radially outward from the rim.

Fig. 3 illustrates a diagram of one possible apparatus configuration.

Fig. 4 illustrates a diagram of an alternative apparatus configuration.

Fig. 5 illustrates a tire building drum with a rubber strip, an integrated chip and an inner liner.

10 Fig. 6 illustrates a side view of an alternative embodiment of a chip/antenna arrangement.

Fig. 7 illustrates a bottom view of the arrangement of Fig. 6.

Fig. 8 illustrates a chip with leads aligned with the carcass ply cords in a tire.

Fig. 9 illustrates an alternative configuration of the antenna of the invention.

Best Mode for Carrying Out the Invention

15 Industrial Applicability

An annular apparatus for electronically transmitting pneumatic tire or wheel identification or other data is provided. The apparatus comprises a transponder, including an integrated circuit chip and at least first and second electrical conductors coupled to the chip. The chip, upon externally-induced radio-frequency excitation, causes the data to be sequentially output from the
20 chip as a voltage appearing between the first and second conductors. An antenna, which together with the transponder has an annular configuration and is coaxial with the tire or wheel. The antenna comprises springy steel wire, and in an illustrated embodiment, a filament wire wound into a helix and having a wire diameter of 0.04mm to 0.4mm.

As used herein, first and second conductors may be one wire circumventing a tire, wherein
25 the first conductor is the end of the wire associated with one terminal of the transponder, and the second conductor is the end of the wire associated with the second terminal of the transponder.

The apparatus is substantially enclosed by nonconductive rubber and is located within the toroidal region of the tire.

The transponder is embedded in nonconductive materials to prevent significant shunt or
30 electrical conduction between chips and the antenna which may be disposed over the chip. The antenna portion has a conformational relationship that permits 150 to 2000% elongation or more, of the antenna. In the illustrated embodiment, the antenna portion is disposed around the EP of a

tire in which it is incorporated.

Conductive rubber can be used to provide connection between various leads of the antenna and transponder. The conductive rubber has a tensile modulus of 300 to 400psi at 50% elongation, an elongation of 270 to 350%, a max tensile of 1800-2100 psi, brass coated steel wire/rubber
5 adhesion of approximately 50 newtons force (75% rubber coverage) and T_{90} cure time of 30 minutes.

Also provided is an antenna designed to receive a signal from a transmitting device for electronically activating the electronic circuit of the chip and for transmitting data from the electronic circuit to a receiving device.

10 Also provided is a pneumatic tire comprising at least two parallel annular beads, carcass plies wrapped around the beads, tread disposed over the carcass plies in a crown area of the tire, sidewalls disposed between the tread and the beads, and a sensing system disposed radially inward of the inner liner. The sensing system comprises the apparatus of the invention as described.

Description of the Invention

15 With reference now to Fig. 1, a tire 10 is illustrated which incorporates a transponder system 30, or signal generator, which can be used to provide tire data such as the inflation pressure within the tire, the temperature of the tire, and the tire identification. As is conventional in the art, the tire is made using at least one pair of annular beads 12 over which is wrapped at least one carcass ply 16. Belts 18 are disposed over carcass ply 16 in a crown area of the tire, and tread 20
20 is disposed over belts 18. Sidewalls 23 are disposed between tread 20 and beads 12. In the illustrated embodiment, the tire also has an innerliner 14 which is disposed radially below carcass ply 16.

The tire illustrated is an RMT (radial medium truck tire), but those skilled in the art will recognize that the apparatus of the invention may have utility in passenger tires, or any tire for
25 which data on the history or the current condition of a tire is needed.

A tire, depending on the kind, may have up to 4 pairs of beads, up to 12 carcass plies, and up to 12 belts.

With reference also to Fig. 2, in the illustrated embodiment, transponder system 30 is disposed under the center of the tread, i.e. at the equatorial plane (EP) of the tire, and radially
30 below carcass ply 16 and innerliner 14. Transponder system 30 comprises one or more integrated circuit chips 28, antenna 26 and any ancillary components needed for obtaining different kinds of data that may be desired, such as pressure sensors and the like. It is believed that this location in

the tire provides the most accurate data, and makes the data of the tire more easily accessible whether the tire is mounted on a vehicle or stacked in the warehouse, since the data can be retrieved by bringing an interrogator near the tread at any portion of the tread around the 360° circumference of the tire.

5 Transponder system 30 is similar to that illustrated in U.S. Patents 5,181,975 and 5,218,861, assigned to The Goodyear Tire and Rubber Company, and commonly assigned Attorney's docket Nos. DN1997-192, 1997-194 and 1997-195, which provides identification data for the tire, and may be used to monitor tire pressure, the temperature of the tire, and the like. In the illustrated embodiment, the two to six chips of the transponder are enclosed in a hard plastic
10 package containing all the circuitry needed to activate each of the chips. The chip package used in the illustrated embodiment was prepared for the inventors by Phase IV Engineering.

Antenna portion 26 may comprise any metal which provides conductivity sufficient to maintain an electrical circuit under the conditions in which it is employed in a tire, and can be drawn to a small diameter. The rubber of the tire will surround the wire of the antenna when the
15 tire is molded.

Because of the expansion steps required in tire building, antenna 26 may be made of springy wire 26a capable of the kind of expansion required in the building of the tire. The wire may be helically wound, crimped to provide wavy wire, or otherwise twisted or folded so that substantial expansion of the wire is possible when needed. In the illustrated embodiment, the
20 antenna is a spring wherein the helix of the spring has a lay length equal to the diameter of the wire to about five times the diameter of the wire.

Consistent with the description in U.S. Patent 5,279,695, the preferred wire used for the antenna of the invention is commonly known as carbon steel, which is also called high-carbon steel, ordinary steel, straight carbon steel, and plain carbon steel. Examples of such a steel are
25 American Iron and Steel Institute Grade 1070 and 1080-high carbon steel (AISI 1070 and 1080). Such steel owes its properties chiefly to the presence of carbon without substantial amounts of other alloying elements. U.S. Patent No. 4,960,473 discloses some preferred steel alloys and a process for manufacturing steel filaments which can be utilized in this invention. Those skilled in the art will recognize that other steels with higher carbon content and containing micro alloying elements
30 such as chromium and boron can also be used.

As an alternative embodiment, the inventors herein speculate that copper clad steel will provide an antenna wire with particularly enhanced conductivity.

Brass is an alloy of copper and zinc which can contain other metals in varying lesser amounts. Alpha-brass, which contains from 63 % to about 99 % copper and from about 1 % to about 37 % zinc, is generally used in coating filaments for utilization in manufacturing filament and cables for reinforcing rubber articles. It is normally preferred for the brass to contain from about
5 62 % to 75 % by weight of copper and from 38 % to 25 % of zinc. Iron-brass alloys, as described in U.S. Patent No. 4,446,198, can be utilized as well as other coatings, for example, zinc.

The helical antenna can be manufactured by using a spring-making apparatus such as a Torrin model W-100. The finish spring can be further annealed at 260°C for one hour to relax the spring to improve handling during assembly. The spring can be produced with various overall
10 diameters, preferably 0.4 to 2 mm, with about 1mm being preferred.

The wire used in antenna portion 26 may have any diameter suitable for a specific application. In normal use it is believed that wire diameters of 0.04 to 0.4mm will have general utility. Preferably the wire diameter will be in the range of 0.06 to 0.2mm in passenger and radial medium truck (RMT) tires. In the illustrated embodiment, the wire has a diameter of 0.15mm.

During the construction of a tire, there are three expansion changes within the tire structure which together cause the tire to expand 128 % to 133 % from its size on the building drum, see Fig.
15 5. An antenna with an expansion of 150 % to 2000 %, preferably 200 % to 1000 % will have utility in the invention. The wire construction used in the illustrated embodiment may provide a design expansion of the antenna of as much as 1000 %, or more. To minimize the resistance of the wire
20 portion of the antenna, in the illustrated embodiment about 2 feet of spring wire is stretched to cover 6 feet of the tire circumference.

Antenna portion 26 may be provided, in the illustrated embodiment, in one to three turns around the tire. Although a sufficient signal may be obtained with one turn of antenna portion 26, the signal is boosted as additional turns are added since the amount of current developed is
25 dependent on the number of lines of magnetic flux encountered by the antenna in accordance with Ampere's law. The efficiency of the antenna can also be improved by increasing the thickness of the brass coating on the antenna wire or by using copper clad steel in the antenna wire.

In the illustrated embodiment, chip 28 and antenna 26 are contained within non-conductive rubber strip 22, radially inward of the inner liner 14. Non-conductive rubber strip 22 may be 1/2
30 inch to four inches wide, and in the illustrated embodiment is about 1 inch wide.

With reference to Fig. 2, in the illustrated embodiment two turns of antenna wire 26 are used. One turn passes over chip 28 but is insulated from chip 28 by a layer of high insulating

epoxy 24.

With reference now to Fig. 3, in an alternative lay-up of the apparatus, two turns of antenna 26 are achieved by cutting of the leads 32 of integrated chip 28 and electrically connecting, such as soldering or embedding in conductive rubber, a first end 34 of one antenna wire 26 across leads 32 and embedding second end 36 in a conductive rubber 40, and a second antenna wire 26a is disposed in the same manner across leads 32a with a first end 34a being electrically connected to leads 32a and a second end 36a being embedded in conductive rubber 40. A section of the antenna 38 may be continuous over conductive rubber 40 or may be severed and connected at section of antenna 38 for ease of construction. Those skilled in the art will recognize that the extra turn of antenna 26 may be wound away from chip 28, instead of being disposed over chip 28. Compare Figs. 2 and 3.

Those skilled in the art will recognize that conductive rubber can be used wherever electrical connection between the antenna and the chips, or between portions of the antenna, is needed.

In an alternative lay-up, as illustrated in Fig. 4, two separate conductive rubber strips 40 may be employed to provide electrical connection between the two ends of antenna 26 and the two sets of leads 32. In such an embodiment, antenna wire 26 may be continuous.

When a conductive rubber matrix 40 is employed, it is preferred that a rubber matrix having a resistivity of 0.1-100 Ohm·cm be used. In the illustrated embodiment, rubber matrix 40 has an electrical resistivity in the range of 5-50 ohm·cm, and in the specific embodiment has a resistivity of 7 ohm·cm.

When rubber is stretched, its resistivity increases, and the 7 ohm·cm resistivity for the illustrated embodiment is obtained in the non-stretched rubber. When stretched 17%, the resistivity in the conductive rubber in the illustrated embodiment is about 10 ohm·cm.

Epoxy used to insulate the chip in the illustrated embodiment is Dexter/Hysol FP4323.

The rubber used to insulate the chip and the antenna, is a non-conductive rubber that has a low loading, in the range of 0 to 10 phr, of non-conductive carbon black.

Insulating rubber must have properties which are consistent with its use in the tire. The insulating rubber used in the illustrated embodiment has a tensile modulus of 1240 to 1440 psi, an elongation at break of 585 to 785 %, a Shore A hardness of 44 to 48, a 50 % modulus of 65 to 80 psi, a T_g of 7 to 16 mins and specific gravity (sg) of 1.04 to 1.09.

Examples of insulating and conductive rubbers that may be used in the invention are

described in U.S. patent application 08/814,957, filed March 10, 1997.

With reference now to Figs. 6 and 7, in an alternative embodiment of the chip 28 of the invention, chip 28 comprises a pressure sensor 64, in addition to other circuitry described above, and has contacts 62 on the opposite side of chip 28a from pressure sensor 64 and epoxy walls 66
5 dividing the bottom of chip 28a into sections. The channels 68 between walls 66 provide a route for helical wound antenna 26 to pass by or near chip 28a and contacts 62, while insulating the different turns of antenna 26 from each other and from chip 28a. Contact 62 may preferably be copper and may be flat or have a notch or hook or some other means to snag antenna 26 to help maintain contact.

10 With reference to Figs. 3 and 5, in the illustrated embodiment, when the tire is manufactured, a layer of nonconductive rubber 22, about one inch wide, is placed around the center of the building drum. A chip 28 is placed on the nonconductive rubber, and the antenna 26 is disposed around the rubber strip 22 in a loop, and the antenna 26 is electrically connected to each of the transponder leads 32. The inner liner is placed over the antenna and the transponder,
15 360° around the tire, insulating the apparatus from the carcass ply and the belt structure which are subsequently added to the building drum.

With reference now to Fig. 8, it has been found that in some tire constructions, aligning a chip 28b of the invention and its leads 32 with cords 82 in a carcass ply during construction of the tire reduces the stress on the chip and its leads 32 because the chip 28b rides with a cord 82 when
20 the cords pantograph during construction, instead of being pulled between two adjacent cords. This helps prevent fracturing of the chip or separating the leads from the antenna during the expansion step of tire construction. For example, if the chip 28b is installed in a bias ply tire where the reinforcement cords are at an angle α of 58° with respect to the center line of the tire, the length direction of the chip package and its opposing leads will be aligned at an angle of 58°
25 with respect to the center line of the tire. Likewise, in a radial tire where the carcass cords have an angle α of 90° with respect to the center line of the tire, chip 28a and its opposing leads 32 will be aligned at an angle of 90° with respect to the centerline of the tire.

Pantographing of carcass cords during construction of a radial tire is not as pronounced as the pantographing of carcass cords in a bias ply tire during construction, but aligning chip 28b with
30 carcass cords 82 may reduce stress on chip 28b and leads 32 in any tire in which it is used. The tire is otherwise constructed in a manner known to those skilled in the art.

With reference to Fig. 9, it has been found that the response to the interrogator can be

enhanced if the impedance of the antenna is closely matched to the impedance of the transponder, i.e. the impedances can be matched so that the antenna uses only the power needed to activate the transponder. The impedance of the interrogator and the transponder are matched using a ferrite core 96 to step up or step down the voltage of the transponder 92 using turns of magnet wire 97a, 5 97b wrapped around ferrite core 96. Accordingly, terminals 98a and 98b connect the opposite ends of turns 97a to opposing ends of antenna wire 91, and terminals 98c and 98d connect the opposite ends of turns 97b to chip 94. In the embodiment illustrated, pressure sensor 95 is located on the same circuit board as chip 94. As will be apparent to those skilled in the art, the function of the transponder and antenna in this embodiment and its construction using conductive rubber may 10 be substantially as in the previous embodiments of the antenna herein described. Because of the enhanced response, antenna apparatus 90 need only comprise a single turn of wire 91.

In the illustrated embodiment of Fig. 9, the transponder package was prepared by Phase IV Engineering, of Boulder Colorado, using a 0.06 inch thick ferrite core having an O.D. (outside diameter) of 0.23 inch and an I.D. of 0.12 inch, cat. Number 5975000101, available from Fair- 15 Rite Products Corp., One Commercial Row, Wallkill, N.Y. 12589. The primary coil 97a was optimized at 19 turns and the secondary coil 97b was optimized at 80 turns using 38 gage copper magnet wire when a brass plated spring antenna wire 91 was used.

In the illustrated embodiment, when transponder system 30 is approached by an interrogator, the interrogator is designed to read the return signal from chip 24. The interrogator 20 transmits at a specific radio frequency and the chip responds by stepping down the signal frequency to transmit one-half the scanner frequency in return. The scanner frequency is heterodyned against the signal frequency producing a difference side band to reinforce the signal response.

While the invention has been specifically illustrated and described, those skilled in the art will recognize that the invention may be variously modified and practiced without departing from 25 the spirit of the invention. The invention is limited only by the scope of the following claims.

CLAIMS

1. A pneumatic tire comprising at least two parallel annular beads, carcass plies wrapped around said beads, tread disposed over said carcass plies in a crown area of said tire, sidewalls disposed between said tread and said beads, and a sensing system disposed radially below said carcass ply and said inner liner, said sensing system comprising an apparatus for transmitting tire data comprising
 - a transponder for responding to predetermined signals which trigger a responsive signal for transmitting data and identification information,
 - a chip associated with said transponder having capacity at least sufficient to transmit pressure data, tire temperature data, and identification information for said tire, and
 - said antenna characterized in that it comprises springy wire associated with leads of said transponder.
2. The pneumatic tire of claim 1 characterized in that said antenna is formed into a loop around the EP of said tire.
3. The pneumatic tire of claim 1 characterized in that said antenna comprises monofilament steel wire having a diameter of 0.04mm to 0.4mm.
4. An annular apparatus for electronically transmitting pneumatic tire or wheel identification or other data, the apparatus comprising:
 - a transponder including an integrated circuit chip and at least first and second electrical leads coupled to the chip, the chip upon externally-induced radio-frequency excitation by an interrogator, causing data to be sequentially output from the chip as a voltage appearing between the first and second leads; and
 - an antenna, which with the transponder is annular in configuration and which is coaxial with the tire or wheel, characterized in that the antenna comprises springy wire associated with the leads of said transponder.
5. The annular apparatus of claim 4, the apparatus being located within the toroidal region of the tire or on the radially outer side of the wheel rim and characterized as being substantially enclosed by nonconductive rubber.
6. The annular apparatus of claim 4, characterized in that the transponder is embedded in nonconductive materials to prevent significant shunt electrical conduction between the chips and the antenna.

7. The annular apparatus of claim 4 characterized in that leads on said circuit chip (28a) comprise contacts (62) and said chip (28a) has non-conductive walls (66) on a side of chip (28a) providing channels (68) for receiving springy wire antenna (26).
8. The annular apparatus of claim 4 characterized in that a transformer equalizes the voltage
5 between an interrogator and the transponder.
9. An antenna for receiving a signal from a transmitting device for electronically activating an electronic circuit containing a transponder and for transmitting data from said electronic circuit to a receiving device, characterized in that said antenna comprises springy wire associated with leads of said transponder.
- 10 10. The antenna of claim 9 characterized in that said wire comprises monofilament wire having a diameter of 0.04mm to 0.4mm.
11. The antenna of claim 9 characterized in that a transformer equalizes the voltage between an interrogator and the transponder.
12. The antenna of claim 9 characterized in that said springy wire comprises a helix having a
15 lay length equal to the diameter of said wire to about 5 times the diameter of said wire.
13. The antenna of claim 9 characterized in that said helix has a lay length of 0.3mm per turn.

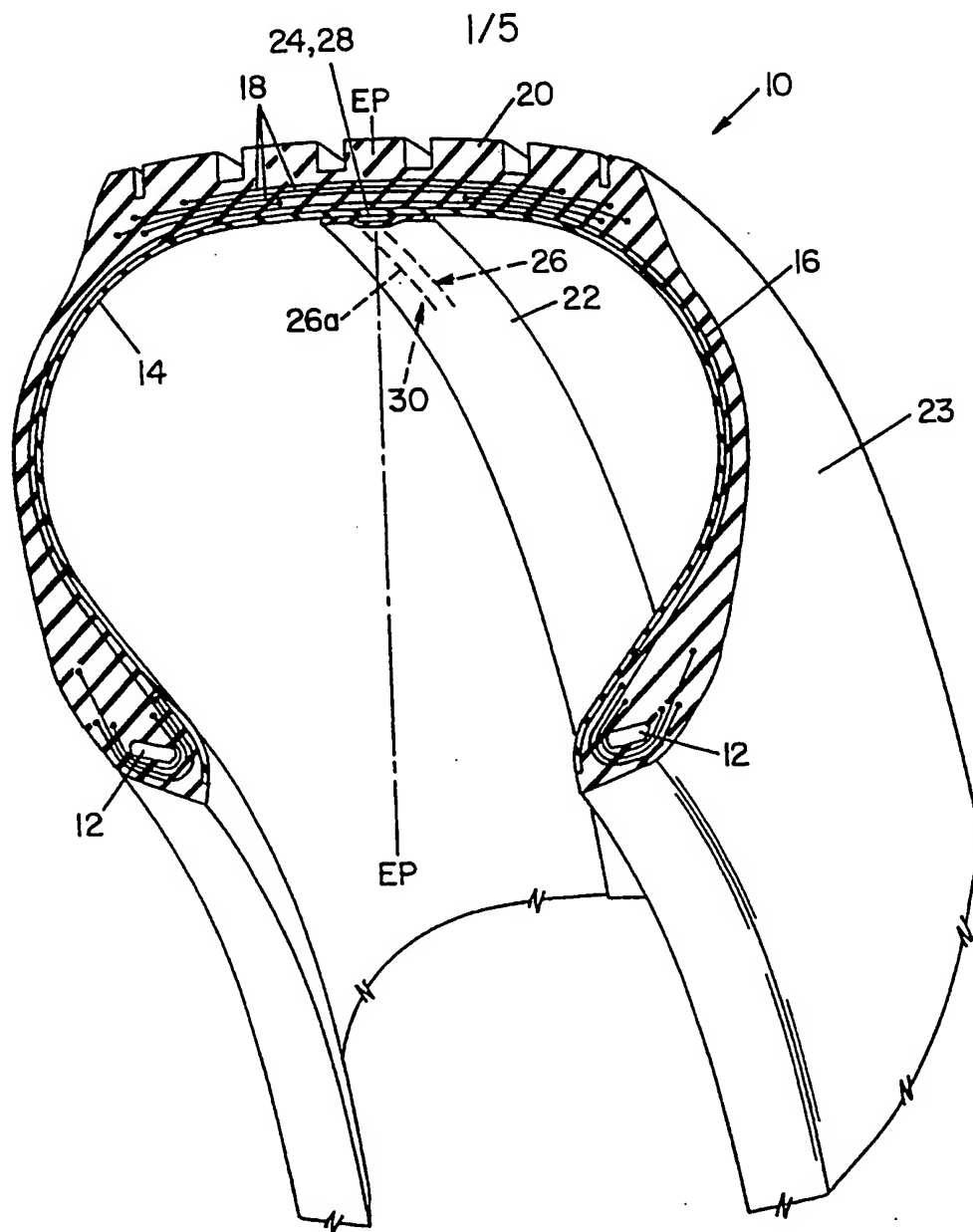
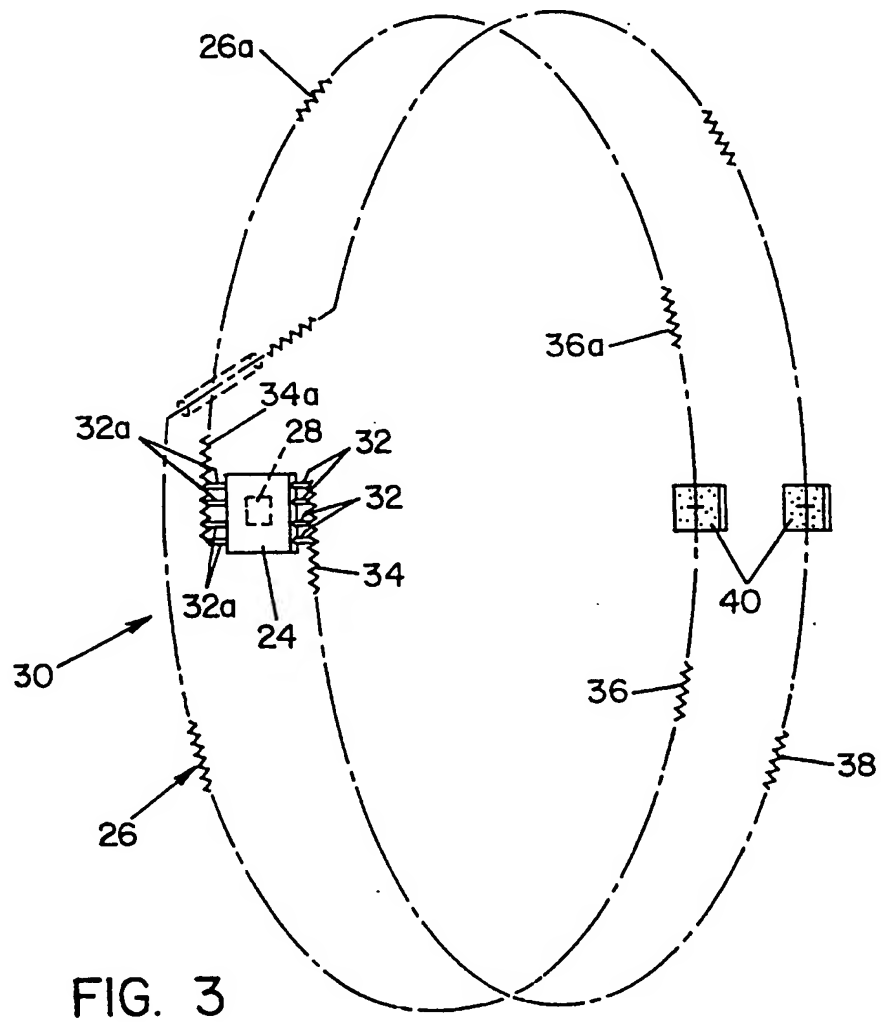
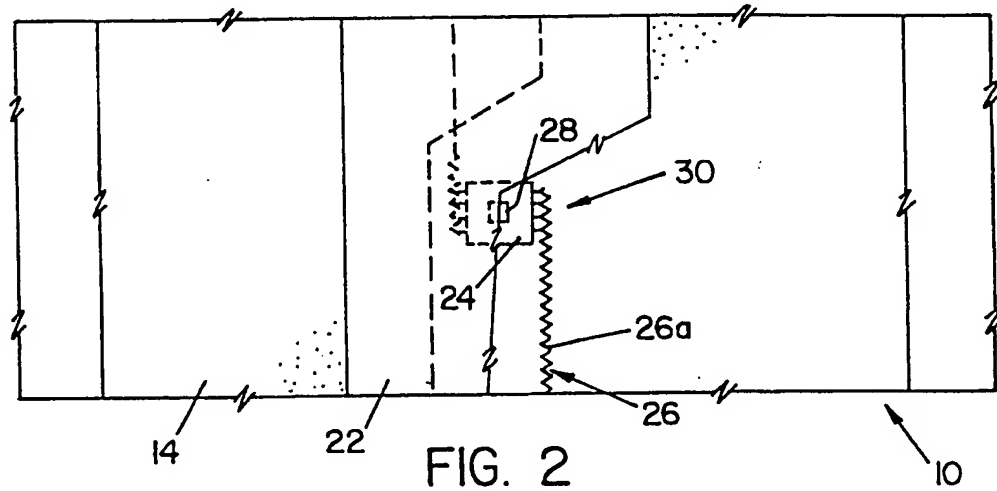


FIG. 1

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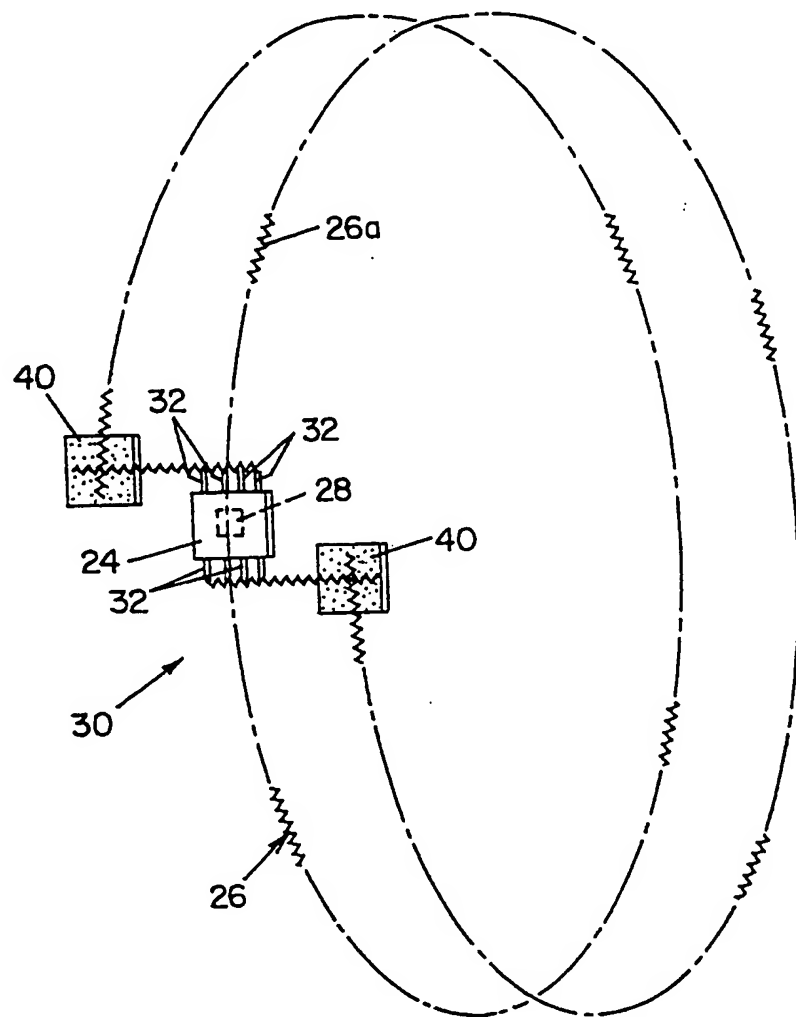


FIG. 4

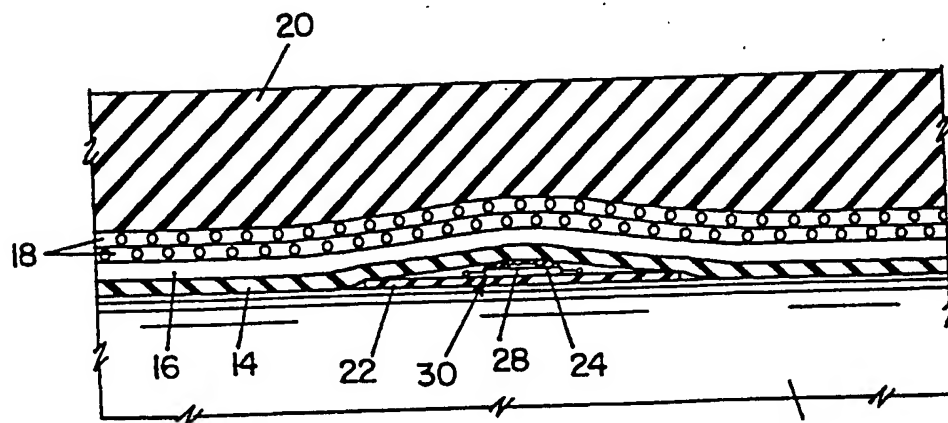


FIG. 5

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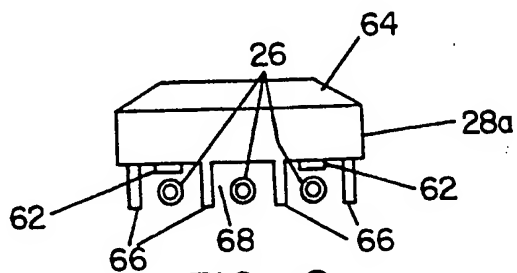


FIG. 6

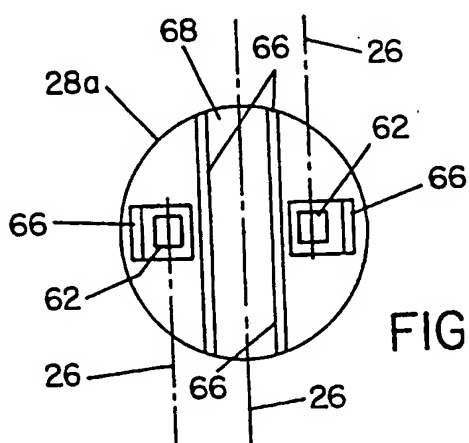


FIG. 7

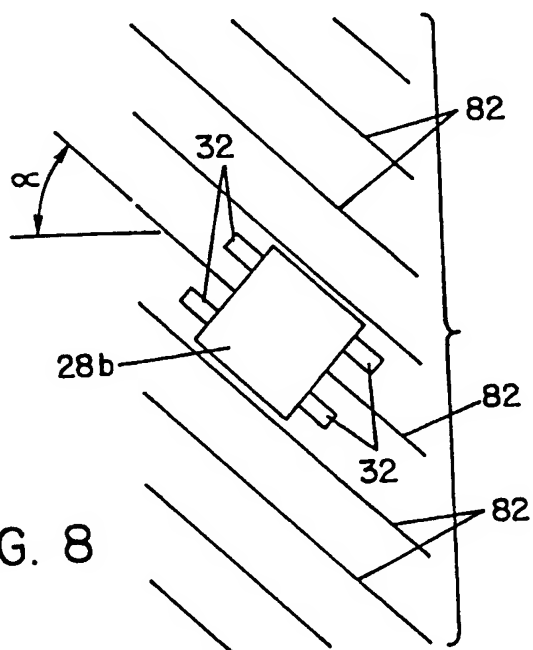


FIG. 8

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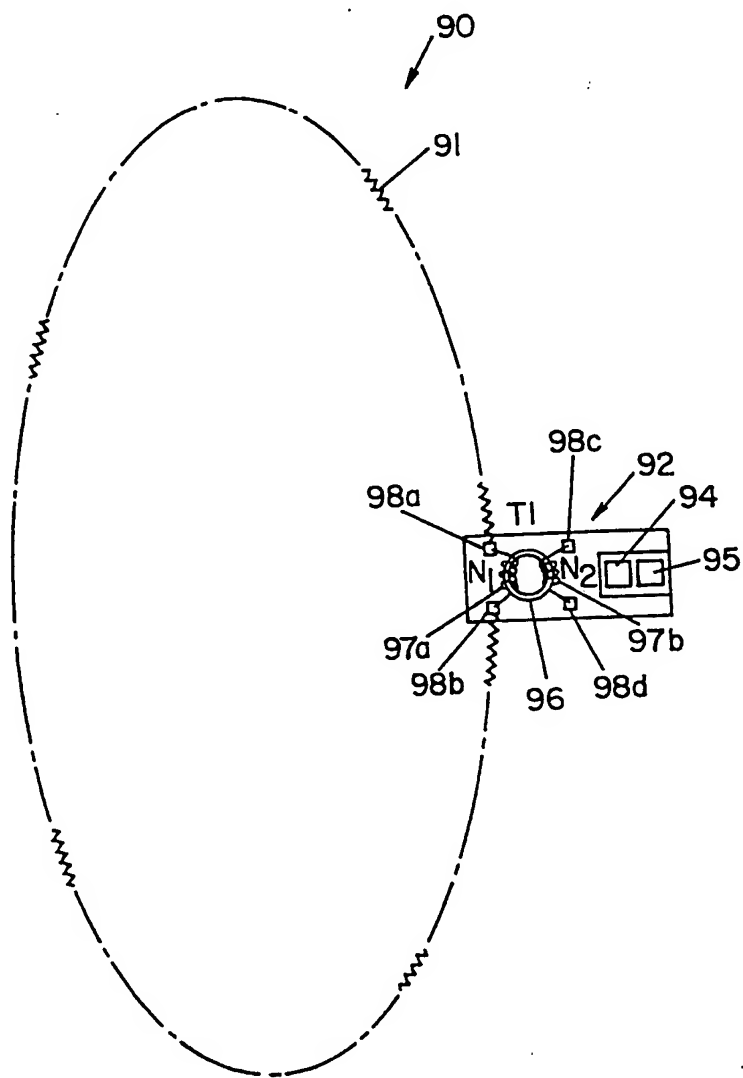


FIG. 9

INTERNATIONAL SEARCH REPORT

national Application No
PCT/US 97/22463

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60C23/04

IPC 6 B60C23/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60C

IPC 6 B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

C. DOCUMENTS CONSIDERED TO BE RELEVANT	
Category *	Citation of document, with indication, where appropriate, of the relevant passages

Relevant to claim No.

X

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1997
see column 6, line 22 - line 48
see column 11, line 31 - line 62
see column 12, line 41 - line 44
see column 13, line 23 - line 54; claim
17; figures 2, 10-12, 14

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9

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X

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July 1996
see column 2, line 1 - line 17; figures
1,3,4

1,4,9

-/-

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

Date of mailing of the international search report

5 August 1998

13/08/1998

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INTERNATIONAL SEARCH REPORT

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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